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Description

Method for optical transmission of a polarization division multiplexed signal

The invention relates to an improved method for optical transmission of a polarization division multiplexed signal.

The transmission of data in polarization division multiplex whereby two optical data signals have the same wavelength with orthogonal polarizations is a highly promising method of doubling transmission capacity without having to place more exacting requirements on the transmission link or signal-to-noise-ratio.

However, a disadvantage of polarization division multiplex is susceptibility to polarization mode dispersion (PMD) which results in mutual interference between the transmission channels. Although the effect of PMD can be reduced by PMD compensation measures, compensation is required for each channel of a wavelength division multiplex system; it is also complex/costly and does not always produce the desired results. The use of PMD-optimized fibers likewise provides an improvement, but is only possible for new networks.

New possibilities with the object of reducing PMD interference susceptibility and therefore mutual interference of the optical data signals during transmission of a PolMUX signal are therefore required.

This object is achieved by a method as claimed in claim 1.

Advantageous further developments of the method are set forth in the sub-claims.

The method is simple to implement. The carrier signals, derived from the same laser source, of the two optical data signals (PolMUX channels) are mutually phase shifted by a constant 90°. Obviously the two carrier signals therefore also have exactly the same frequency and their phase difference remains constant during transmission. The phase can be adjusted at the transmitter end by different devices such as phase modulators and delay elements.

Also advantageous is the use of a phase control arrangement which ensures a constant phase difference between the carrier signals irrespective of the environmental conditions and component tolerances.

The invention will now be described in greater detail using examples and with reference to the accompanying drawings in which:

Figure 1 shows a circuit diagram of the transmit arrangement,
Figure 2 shows a circuit diagram with phase control,
Figure 3 shows a phase difference measuring arrangement,
Figure 4 shows another phase difference measuring arrangement and
Figure 5 shows an arrangement for phase difference measurement by analyzing orthogonal signal components.

Figure 1 is a circuit diagram of the transmit arrangement. The method can also be implemented by any desired variants of this arrangement. A constant wave (CW) optical signal normally generated by a laser is fed via an input 1 to a polarization splitter 2 which splits it into two orthogonal carrier signals CW_X and CW_Y of equal amplitude but having planes of polarization differing by 90° (the arrows indicate the

relevant polarization). The orthogonal carrier signal CW_X is fed via a first optical fiber 3 to a first modulator 5 where it is intensity modulated with a first data signal DS1. The second orthogonal carrier signal CW_Y is fed via a second fiber 4 and a phase shifter 6 to a second modulator 7 where it is intensity modulated with a second data signal DS2. The optical data signals OS1 and OS2 produced at the outputs of the modulators and which are orthogonally polarized relative to one another and whose carrier signals are phase shifted by 90° are combined in a polarization combiner 8 to form a polarization division multiplex signal (PolMUX signal) PMS and fed out at output 9. Both the phase shift between the two carrier signals and the polarization can likewise be adjusted after the modulators.

Figure 2 shows such a variant in which the carrier signal CW is first split, in a power splitter 13, into two equal components CW1 and CW2 which are modulated as carrier signals with data signals DS1 and DS2 respectively. Conversion into two orthogonal optical data signals OS1 and OS2 is accomplished by two polarization controllers 14 and 15 which are disposed preceding the polarization combiner 8 and naturally also then convert the carrier signals CW1 and CW2 into the orthogonal carrier signals CW_X and CW_Y.

The phase shift between the carrier signals CW1 and CW2 is created by a controlled phase shifter 10 (phase modulator, delay element) which is controlled by a control device 11. Said control device 11 receives, via a tap 12, a lower-power measurement signal MS corresponding to the PolMUX signal PMS and monitors the phase shift between the carriers of the orthogonal data signals OS1 and OS2. The time constant of the control device is selected very large so that the controlled phase shifter 10 has a virtually constant value. The phase

shifter 10 can likewise be connected following the polarization controller 15. The carrier signals can therefore be phase shifted by adjusting the carrier signals CW_X and CW_Y or CW1 and CW2 or the orthogonal data signals OS1 and OS2.

A control criterion for the carrier phases can always be obtained without great complexity if the two PolMUX channels simultaneously transmit a signal, e.g. if the two signals correspond to a logical one.

Figure 3 shows a circuit diagram of the control device for obtaining a control criterion. The measurement principle is based on the fact that the state of polarization depends on the phase between the two polarized signals OS1 and OS2 and the phase difference can therefore be determined by measuring the state of polarization. It is only necessary to measure the circular polarization component. To measure same, the measurement signal MS, which like the PolMUX signal has a particular polarization, is split into two sub-signals, one of which is fed via a $\lambda/4$ plate and a 45° polarizer (polarization filter). At precisely 90° phase displacement of the carrier signals relative to one another the amplitudes of the two sub-signals OA and OB are of equal size. The optical sub-signals OA and OB are converted by photodiodes 18 and 19 into electrical sub-signals EA and EB and fed to a controller 20 which measures the amplitude difference and adjusts the phase difference of the carrier signals accordingly.

Figure 4 shows another possibility for determining the phase difference by using what is known as a DGD (differential group delay) element such as a polarization-maintaining fiber or birefringent crystal which reverses the 90° phase shift of the carrier signals so that their superimposition produces maximum power (or, in the case of opposite phase displacement, minimum

power) in the output signal RS. The polarization planes of the orthogonal signals OS1 and OS2 must be at 45° to the main axes of the DGD element. After conversion of the optical superimposition signal OTS into an electrical superimposition signal ETS in a photodiode 22, the effective power is determined in a control device 23 and adjusted to a maximum (or minimum).

Figure 5 shows another arrangement for controlling the phase. The requirement is again that the PolMUX signal PMS or rather the corresponding measurement signal MS has a particular polarization, as is the case anyway, however, for the transmitter. The PolMUX signal or rather the measurement signal here has two (at least virtually) orthogonal signals OS1 and OS2 polarized +45° and -45° relative to a polarization plane of the polarization splitter 24. The measurement signal MS representing the two orthogonal signals OS1 and OS2 is decomposed by the polarization splitter 24 into two polarized signal components OS_X and OS_Y which therefore contain signal components of the two orthogonal signals OS1 and OS2. The signal components MS_X and MS_Y are separately converted into electrical signal components E_X and E_Y in photodiodes 18 and 19. Only when there is a particular phase between the orthogonal signals OS1 and OS2 will the two signal components MS_X and MS_Y be of equal magnitude. A corresponding criterion EA - EB can be used for control. The sensitivity of the control system can be increased by special signal processing in the control device 25, e.g. by multiplication of the signal components.